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UNITED STATES DEPARTMENT OF AGRICULTURE • Economic Research Service

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AGRICULTURAL ECONOMICS RESEARCH VOL. 22, NO. 2, APRIL 1970

A Simple, Two-Region Simulation of Population, Income, and Employment

By Clark Edwards

As a nation develops, some geographic regions are observed, always, to grow faster than others. Regional analysis of trends in population, income, and employment is needed to help explain regional variations in business activity. Linkages between regions are frequently measured in terms of exchange of final products, capital flows, or migration. Impacts of such exchanges may be assessed on prices, earnings, money supply, and other economic variables. Within the markets of the United States, exchanges of goods and consequent impacts on commodity prices are relatively unhampered; migration of persons and differential earnings constitute what is perhaps a more dramatic aspect of interregional exchange.

This paper presents and discusses a simple simulation model which follows alternative time paths of population, income, and employment in a two-region model for the United States. The connecting link between the two regions is migration. The model contains seven variables, the minimum number that can be used to describe three variables in each of two regions plus one interaction variable. Interpretive results of the model were reported elsewhere.[1] The present paper is concerned more with an explication of the analytic technique than with the economic interpretation of the results, although the general nature of the problem and implications of the model are summarized below. The model was tested by comparing the 10 Great Plains States[2] with the other 40 States. However, the problem studied is not unique to the Plains.

The Problem

Relative to the rest of the economy of the United States, the Great Plains States exhibit, in some respects, many characteristics of a depressed area. Income per capita is lower there than in the United States as a whole; and the dollar gap in incomes per capita is widening. People are leaving agriculture there as everywhere; that is a national phenomenon. But residents of the Plains are having more than average difficulty finding nonfarm job opportunities near home. Some seek work in the major cities of the Plains, thus depopulating the small towns and rural places. With a shortage in the Plains of metropolitan development, particularly that related to manufacturing employment, there is considerable migration to cities outside the Plains. Capital flows from savings in the Plains to investments elsewhere. Creation of community investments is slowed for needed schools, roads, recreational facilities, utilities, residential and business areas, and other facilities which flow from local, group action. Depopulation of the hinterlands reduces the demand for the services of central cities and slows the development of social, political, and economic institutions, requiring residents of the Plains to depend in part on institutions outside the region for centralized services. Circularly, the arrested development of the economy in the Plains induces further outmigration.

The 10 States known as the Great Plains contain about 11 percent of the U.S. population but only 10 percent of the jobs and income. Since 1960, the population of the Plains has grown around 1.2 percent per year (see footnote 1). This compares with 1.4 percent for the Nation. The difference appears to reflect net migration influences rather than basic differences in natural increase. A look at county migration patterns makes apparent large areas of population decline in each of the 10 Plains States. The declining counties tend to be in the more sparsely populated, rural areas. Two net migration patterns emerge which are relevant to the present discussion: One a movement from rural to urban places within the Plains leaving vast areas with a sense of depression; the other a net movement from the 10 Plains States into the other 40.

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[1] Clark Edwards. Creating off-farm employment in the Great Plains. Great Plains Agr. Council Proc., Oklahoma City, Okla., July 30-August 1, 1969.

[2] North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, New Mexico, Colorado, Wyoming, and Montana.

Personal income has been rising in the Plains at a pace of about 6.7 percent per year. With a gain of only 1.2 percent per year in population, this has resulted in rapidly rising incomes per capita, to a level of around $3,040 in 1968 from $1,990 at the beginning of the decade. But incomes rose faster in the other States, both in the aggregate and on a per capita basis. Per capita income in 1968 in the other 40 States averaged $442 higher than in the Plains.

If the objective is to seek more equal incomes among regions, then a benchmark for measuring progress in the Plains is apparent: Incomes per capita in the Plains would have to have gained at a pace of around 6.2 percent per year to have kept the dollar gap at its 1960 size of $264. Growth was slower than this and allowed the gap to widen during 1960-68; growth faster than this would have been required to close the gap and bring about equal incomes. The reported growth rate for per capita income was only 5.4 percent per year. The trend is evidently toward intensification of the income disparity.

Current trends suggest that over the next few decades, population in the Plains will continue to rise more slowly than in other States and the rate of outmigration will increase (table 1, rows 1 and 2). The gain in per capita incomes in the Plains is likely to be at an annual rate close to that of other States, resulting in a further widening of the dollar gap in incomes. Part of the gain in per capita incomes is likely to come through increased labor force participation and its concomitant reduction of dependent population, but labor force participation is likely to continue below the rate of other States.

These results are tabulated in fuller detail in table 2. Tables 3 through 8, summarized in table 1, show details of possible consequences of alternative policies affecting the Great Plains economy with respect to migration, natural population increase, growth in aggregate demand, and increases in productivity per worker. Before discussing the results of these alternatives, let us explain the assumptions and methods underlying the construction of tables 2 through 8.

The Model

Seven variables are used to describe the system in each year of the simulation: population, income, and employment in each of the two regions plus the number of migrants from the Plains to other States.

Six of these variables--population, income, and employment in each of the two regions--were assumed known as initial conditions for the first year of the simulation. The approach was to test the model using 1960 initial conditions. Parameters (discussed below) which led to a close approximation for available estimates for 1967 were assumed to be useful parameters. The model was then initialized to 1967 and run for a 50-year simulation of the seven descriptive variables. Tables 2 through 8 report the results for 5 selected years from the 50-year run. Table 1 facilitates comparisons of alternative runs as of the year 2000 with each other and with an approximation of the current (1970) situation.

Seven equations were required to describe the system:

Employment growth equations.--For each region, employment in a given year was equal to employment in the preceding year plus the number of added workers absorbed from the nonworking population.

$$E_{1,t+1} = E_{1,t} + a_1 (P_{1,t} - E_{1,t})$$

$$E_{2,t+1} = E_{2,t} + a_2 (P_{2,t} - E_{2,t})$$

where E is employment, P is population, a is the demand coefficient, subscripts 1 and 2 refer to regions 1 and 2, and subscripts t and t+1 refer to successive years.

Income growth equations.--For each region, income in a given year was equal to the product of three terms: the growth in income and output per worker, the growth in the number of workers, and the level of income in the preceding year.

$$Y_{1,t+1} = (1 + b_1) (E_{1,t+1}/E_{1,t}) (Y_{1,t})$$

$$Y_{2,t+1} = (1 + b_2) (E_{2,t+1}/E_{2,t}) (Y_{2,t})$$

where Y is aggregate income of the region and b reflects the annual rate of gain in productivity and, by implication, earnings per worker.

Population growth equations.--For each region, population in a given year was equal to population in the preceding year plus natural increase plus (minus) migration to the other region.

$$P_{1,t+1} = (1 + c_1) (P_{1,t}) - M_t$$

$$P_{2,t+1} = (1 + c_2) (P_{2,t}) + M_t$$

where M is the migration to region 2 from region 1 and where c is the annual rate of natural increase.

Table 1.--Summary of projections and simulated alternatives for economic development in the Great Plains with comparisons

Year	Source (table number)	Population growth per year		Net migration per year from the Plains	Income per capita		Workforce participation per 1,000 population	
		Great Plains	Other States		Great Plains	Other States	Great Plains	Other States
		Percent	Percent	Percent	Dollars	Dollars	Persons	Persons
1970..	2	1.163	1.317	0.138	3,146	3,607	348	362
2000..	2	1.071	1.328	.230	10,345	11,672	353	361
2000..	3	1.300	1.300	.000	9,906	11,733	338	363
2000..	4	.858	1.350	.442	10,767	11,620	367	360
2000..	5	.781	1.323	.217	11,116	11,679	379	362
2000..	6	1.761	1.336	.239	8,764	11,656	298	361
2000..	7	1.111	1.323	.191	10,793	11,684	368	362
2000..	8	1.390	1.289	-.091	11,735	11,717	342	363

Source: Tables 2 through 8.

Table 2.--Projection of recent economic trends in the Great Plains*

Year	Population		Employment		Personal income		Migration per year from Great Plains to other States
	Great Plains	Other States	Great Plains	Other States	Great Plains	Other States	
	Thous.	Thous.	Thous.	Thous.	$1,000	$1,000	Thous.
1970	23,223	182,429	8,076	66,048	73,051	657,832	32
1980	26,045	207,960	9,081	75,253	121,588	1,109,450	41
1990	29,140	237,129	10,205	85,750	202,253	1,871,339	55
2000	32,490	270,491	11,457	97,727	336,107	3,156,928	75
2010	36,048	308,707	12,843	111,399	557,725	5,326,817	105

*Based on projections discussed in text.

Table 3.--Simulated impact of stopping outmigration in the Great Plains*

Year	Population		Employment		Personal income		Migration per year from Great Plains to other States
	Great Plains	Other States	Great Plains	Other States	Great Plains	Other States	
	Thous.	Thous.	Thous.	Thous.	$1,000	$1,000	Thous.
1970	23,316	182,336	8,077	66,048	73,056	657,825	0
1980	26,530	207,475	9,098	75,233	121,808	1,109,165	0
1990	30,188	236,081	10,265	85,680	203,438	1,869,806	0
2000	34,351	268,630	11,598	97,561	340,257	3,151,579	0
2010	39,087	305,668	13,121	111,076	569,770	5,311,333	0

*Differs from table 2 in that the propensity to migrate is set equal to zero.

Table 4.--Simulated impact of doubling the rate of outmigration in the Great Plains*

Year	Population		Employment		Personal income		Migration per year from Great Plains to other States
	Great Plains	Other States	Great Plains	Other States	Great Plains	Other States	
	Thous.	Thous.	Thous.	Thous.	$1,000	$1,000	Thous.
1970	23,132	182,520	8,076	66,049	73,046	657,839	63
1980	25,595	208,411	9,066	75,271	121,379	1,109,722	77
1990	28,204	238,065	10,150	85,814	201,163	1,872,747	101
2000	30,871	272,110	11,330	97,875	332,388	3,161,720	137
2010	33,446	311,308	12,600	111,684	547,143	5,340,416	191

*Differs from table 2 in that responses to inducements to migrate are multiplied by a factor of two.

Table 5.--Simulated impact of slowing down the rate of natural increase in the Great Plains*

Year	Population		Employment		Personal income		Migration per year from Great Plains to other States
	Great Plains	Other States	Great Plains	Other States	Great Plains	Other States	
	Thous.	Thous.	Thous.	Thous.	$1,000	$1,000	Thous.
1970	23,018	182,427	8,075	66,048	73,040	657,832	31
1980	25,082	207,928	9,047	75,252	121,129	1,109,437	36
1990	27,283	237,024	10,090	85,745	199,968	1,871,223	47
2000	29,576	270,274	11,206	97,711	328,757	3,156,414	64
2010	31,884	308,333	12,396	111,364	538,295	5,325,130	91

*Differs from table 2 in that the natural rate of increase is reduced to 1.0 percent per year in the Plains while held at 1.3 in other States.

Table 6.--Simulated impact of expanding the rate of natural increase in the Great Plains*

Year	Population		Employment		Personal income		Migration per year from Great Plains to other States
	Great Plains	Other States	Great Plains	Other States	Great Plains	Other States	
	Thous.	Thous.	Thous.	Thous.	$1,000	$1,000	Thous.
1970	23,706	182,431	8,079	66,048	73,078	657,832	35
1980	28,435	208,033	9,164	75,255	122,700	1,109,480	52
1990	34,001	237,357	10,495	85,762	207,999	1,871,595	72
2000	40,547	270,956	12,112	97,761	355,317	3,158,048	97
2010	48,213	309,492	14,061	111,475	610,596	5,330,437	131

*Differs from table 2 in that the natural rate of increase is increased to 2.0 percent per year in the Plains while held at 1.3 in other States.

Table 7.--Simulated impact of expanding aggregate demand in the Great Plains*

Year	Population		Employment		Personal income		Migration per year from Great Plains to other States
	Great Plains	Other States	Great Plains	Other States	Great Plains	Other States	
	Thous.	Thous.	Thous.	Thous.	$1,000	$1,000	Thous.
1970	23,242	182,410	8,127	66,048	73,511	657,831	25
1980	26,149	207,856	9,310	75,249	124,649	1,109,390	32
1990	29,362	236,907	10,627	85,735	210,614	1,871,012	44
2000	32,863	270,118	12,090	97,692	354,687	3,155,809	63
2010	36,606	308,148	13,709	111,335	626,821	5,323,713	95

*Differs from table 2 in that the growth in aggregate demand for workers is set equal to the rate in other States. In table 2, demand in the Plains absorbed only 83 percent as much of the available labor as would have been absorbed in other States.

Table 8.--Simulated impact of increasing the productivity per worker in the Great Plains*

Year	Population		Employment		Personal income		Migration per year from Great Plains to other States
	Great Plains	Other States	Great Plains	Other States	Great Plains	Other States	
	Thous.	Thous.	Thous.	Thous.	$1,000	$1,000	Thous.
1970	23,226	182,426	8,076	66,048	74,110	657,832	29
1980	26,142	207,864	9,083	75,250	129,438	1,109,416	23
1990	29,569	236,700	10,220	85,732	226,180	1,870,944	6
2000	33,730	269,251	11,517	97,656	395,807	3,154,652	-30
2010	39,004	305,751	13,017	111,196	694,753	5,317,067	-103

*Differs from table 2 in that the annual gain in productivity per worker and in earnings was set at 4.5 percent per year in the Plains while that in other States was held at 4.0 percent per year.

Migration equation.--Migration to region 2 from region 1 was the sum of three inducements to migrate: regional disparities in aggregate demand, regional disparities in income per worker, and regional disparities in employment opportunities per capita.

$$M_t = d(a_2 - a_1) + e(Y_{2,t}/E_{2,t} - Y_{1,t}/E_{1,t}) + f(E_{2,t}/P_{2,t} - E_{1,t}/P_{1,t})$$

where d is the propensity to respond to a differential in capacity for demand to absorb idle workers, e is the propensity to respond to a differential in earnings per worker, and f is the propensity to respond to a differential in participation of the population in the work force.

The seven equations contain nine parameters, as follows:

The demand coefficient for the Plains was found to be $a_1 = .00630$, that for other States $a_2 = .00745$ on the basis of 1960-67 gains in population and employment. For table 7, $a_1 = a_2 = .00745$.

The productivity coefficient in each region was initially set near the recent national average: $b_1 = b_2 = .04$. This may be a little higher than might be expected to obtain over the next 50 years. In reproducing 1960-67 changes, it picks up part of the recent upturn in general price levels. Observed differences in gains in productivity and income appeared to favor the other States slightly relative to the Plains. The differences were small enough to suggest an advantage to assuming the same rate initially. For table 8, $a_1 = .045$ for the Plains; $a_2 = .04$ for other States.

The population growth coefficient in each region was initially set near current rates: $c_1 = c_2 = .013$. For table 5, $c_1 = .01$ for the Plains. For table 6, $c_1 = .02$ for the Plains.

The three migration coefficients were initially set: d = 5,200, e = .022, and f = 414. These settings attribute about half the total propensity to migrate to the differential in earnings. The other half is about equally divided between the differentials in demand and in labor force participation. For table 3 these three coefficients were set equal to zero. For table 4 these three coefficients were doubled in value.

Application of the Model

Current trends suggest that overt policies with respect to changes in the Plains in income, population, and employment might avert a further divergence in the level of development relative to the other 40 States. Broad policies (reviewed below) focus on migration, natural increase, aggregate demand, and income and productivity per worker.

For example, we hear it said that one way to make the Plains grow is to stop outmigration. Table 3 shows the consequences of doing that. It can add close to 2 million people to the Plains by the year 2000. But fewer than 10 percent of the additions will find employment, given the current job market structure. Work force participation rates may fall to 34 percent of the population from the current level of around 35 percent. Per capita income, as a result, could run more than $400 below what can be expected under current trends. Incomes in the other 40 States, on the other hand, might rise $50 or so above trend in consequence of reduced competition there for jobs, and less unemployment. Stopping outmigration brings about increases in aggregate population, income, and employment, but unless accompanied by other programs will lead to less real income per capita in the Plains than can be expected with current trends.

If stopping outmigration makes things worse, will doubling the rate make things better? Table 4 shows the consequences of doubling the response to inducements to migrate. This cuts the rate of population growth in the Plains to less than 1 percent per year. In a matter of 25 years or so, the problems of unemployment may be taken care of in the Plains under such a policy and workforce participation rates of the population will about equal the average of the other 40 States. And by the year 2000, per capita incomes in the Plains may run as much as $800 above trend although continuing below the average in the other 40 States. These apparent benefits are slow in coming; they are at the expense of slowing down the rate of aggregate growth in general business activity in the Plains and of exporting some unemployment problems to the other States; and they are not sufficient to close the development gap.

The conclusion with respect to migration policies is this: It may be that reduced outmigration is a meaningful target for regional income and employment policy, but manipulating migration rates is not the way to reach income and employment targets. Migration plays the role of an end, not a means.

The population explosion is often blamed for holding progress toward development goals down to a snail's pace. Table 5 shows the consequences of lowering the rate of natural population increase to 1.0 percent per year in the Plains from the 1.3 percent rate used in preparing table 2. This cuts the rate of population increase sharply in the Plains, and with reduced outmigration, cuts the rate of increase in the other 40 States slightly, as well. With less unemployment, income per capita rises in the area as the family planners suggest. At the end of the 50-year simulation income per capita in the area was running only $100 below that in other States. The per capita gains are realized at the expense of reduced total business activity, down about 2 percent below trend by the year 2000.

Were the natural rate of population increase in the Plains to rise instead of fall, a rise in total business activity would be gained at the expense of a deterioration in the rate of improvement in income per capita. Table 6 shows the consequences of stepping up the rate of natural increase in the Plains to 2 percent per year without simultaneously expanding the local economies' ability to absorb workers. A 5 percent larger total economy in the year 2000 is accompanied by a level of income per capita some $1,600 below trend.

The conclusion with respect to population growth policies is this: If one were forced to a choice between either stepping up outmigration or reducing the rate of natural increase as a means of improving per capita income in the Plains, the latter appears preferable to the former. But neither seems to be a very efficient or very satisfactory approach. Each might prove useful as a minor adjunct to other income and employment policies, but neither alone will be likely to carry the burden of solving development problems.

Expanding aggregate demand is the solution to income and employment problems in vogue with economists over the last 30 years. Table 7 shows the impacts of raising to the level of the other 40 States the capacity of the Plains economy to absorb potential workers annually. During 1960-67, the other 40 States were absorbing about 745 workers into the work force each year per million persons not at work. The Great Plains economy was able to absorb 630 workers per year per million persons not at work. Those not at work include persons able to work, such as recent graduates of high schools and colleges, working-age people who have dropped out of the labor force, unemployed, and adults who have never been in the labor force. Those not at work also include, in this method of calculation, persons unable to work such as children, old people, the sick, and other unemployables.

Stepping up the demand for nonfarm employment shows promising potential for closing some of the economic development gap between the Plains and the other 40 States. Even so, this policy followed alone is not likely to be sufficient. While it will work well in the short run, it is not likely to prove a sustainable, long-run means. According to table 7, income per capita rises to a level some $400 above trend by the year 2000 although continuing well below incomes in the other 40 States. With more jobs and more income per capita, outmigration is reduced and the rate of population growth in the Plains increases slightly. And total business activity in the region is indicated around 5 percent above trend by the year 2000.

Pursuing a policy of matching the capacity of the Plains economy to that of the other 40 States to absorb idle workers may be pressing against the limits of feasibility in the long run. Work-force participation rates rise from the current level of 35 percent of the population to the average of other States (36 percent) in 25 years, according to the simulation. It is beyond that point that difficulties of sustaining this policy would become acute. Yet at that point the gap between the level of economic development in the Plains and the other 40 States is not yet closed.

Increasing productivity per worker and reducing the high rate of underemployment in the Plains is an effort to solve the development problem from the point of view of the quality of the supply of labor and its utilization. This is in contrast to the appraisals discussed above which work on the quantity of workers supplied or on the quantity demanded without any changes in the way they do things. Table 8 shows the impacts of raising the level of income and output per worker at a pace of 4.5 percent per year while that in the other 40 States continues to rise at 4.0 percent.

The first striking result of pursuing this policy in the simulations is that it stopped outmigration from the Plains in 25 years. As the run continued through its 50-year period, migrants flowed into the Plains to join its productive work force and share in its economic rewards.

The second striking result is that the gap in per capita incomes between the Plains and other States was closed by the year 2000.

Thirdly, aggregate population, income, and employment rose above the trend line under this policy, due to a substantial rise in total business activity as well as to improved incomes per worker.

Efforts to raise income and output per worker in the Plains make greater demands on policy implementers than the other approaches discussed so far. They also offer greater returns, and appear to be worth the effort. They require significant improvements in programs dealing with health, education, job training, family location, commuting patterns, central city services, and other factors. They require reducing the high rate of underemployment in the labor force of the Plains as well as increasing the capacity of each worker to produce. Both the job and the worker need upgrading. They require changing attitudes of leaders and followers as well as finding new ways of doing things in the Plains.

In summary, the discussion of tables 2 through 8 suggests the following: The level of income and output per worker in the Plains is lower than the average for other States and the gap has been widening. One of the most promising policies for economic development in the Plains appears to focus on stepping up the rate of improvement in quality of the labor force, and the rate of its utilization. Secondly, efforts to expand aggregate demand in the Plains more nearly in line with the rate of expansion in other States will be a useful companion policy to one that improves the productivity of workers. Thirdly, policy makers need not look askance at some moderate reduction in the natural rate of increase of population in the Plains, but overt efforts to make this the objective of development policies do not appear warranted. Stopping outmigration as a natural consequence of following the development policies above might be considered desirable; but using overt migration policies to achieve development ends does not appear warranted. Finally, while there were side effects in the other 40 States, some good and some not, the general level of activity was only moderately affected outside the Plains by development policies within the Plains.

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An Economic Analysis of Farmland Development

By Dale M. Hoover

Farmland has long been regarded as the most nearly perfect example of a fixed resource. Because it is fixed, its return depends on the price of the product it produces and the supply of complementary and substitute inputs. As the classical economists realized, a complex problem can be greatly simplified if the quantity of one factor is assumed to be completely fixed (land) and the supply of another factor (labor) is assumed to be perfectly elastic at a given price (e.g., the subsistence wage). The power of analysis which results from similar simplifying assumptions has been widely recognized. The analysis in some cases has been so powerful that the results of the particular example have been remembered but the limitations of the analysis have been forgotten. In a sense, the classical lesson about land has been learned too well. It may have been true that the supply of land was once fixed but it clearly is not true of farmland in the United States at the present time.[1] Land not now in farm production can be altered and brought into farms. The productivity of land already being farmed can be greatly improved by addition of nonland factors such as drainage and irrigation systems, and through such activities as contouring and leveling.

The extent to which the stock[2] of farmland in the United States has been altered can be demonstrated by using data on drainage and reclamation for the last 60 years. More than 92 million acres in organized drainage districts have been affected by drainage activities since 1910 (17, p. 28).[3] An additional 29 million acres were provided with irrigation facilities between 1900 and 1964 (4, p. 40). These two activities have increased the cropland productive potential by perhaps as much as 22 percent of the 1910 base.[4] Probably the major additions to the land stock have already taken place, but large adjustments are still possible. Additional clearing, drainage, and irrigation activities could conceivably add 200 to 300 million more acres to the farmland stock at some cost (15, p. 13).

Land development activities may be reasonable for individual firms in responding to the costs and returns they face. But large aggregate land development may not be in order at this time. An average of more than 50 million acres of cropland have been diverted annually in the last 5 years with annual Treasury payments for price support and diversion running around $2.5 billion. The diversion programs have made land scarce relative to labor and raised product prices above levels which would otherwise have prevailed. Additions to the land stock over the last two decades may have been as large as the current rate of diversion of the voluntary programs (4; 16, p. 46). Conceivably, history could repeat itself in the next 20 years by reducing the effectiveness or increasing the costs of the diversion programs.

In addition to product price policies, Federal tax policies and input payments may be affecting the rate of land productivity. The major policies of product price enhancement and payments could lead to the creation of a larger

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[1] Some economists may be concerned that little distinction is made in this paper between land and capital as distinct input categories. As assets, land values have many of the same characteristics as nonland capital values. When development is possible but costly, the supply curve of land may have many of the same characteristics as the supply curve of another reproducible capital good. Any further concern about the distinction between land and nonland capital goods should probably turn on the elasticity of substitution in production, which is basically an empirical question.

[2] The stock of land differs from the services of land in that the flow of services from one physical source persists over time. This means the stock can take on a present value of expected future services and be traded in a capital market. Components of the land stock probably include the capability of the soil to serve as a medium for nutrient transfer to plants, the available nutrients themselves, soil moisture, humidity, temperature patterns, and associated physical nonsoil capabilities which become attached to the land and are sold with it.

[3] Underscored numbers in parentheses refer to the Literature Cited, p. 43.

[4] Based on the assumptions (1) that the productivity of land in drainage districts was improved by 50 percent, (2) that the average productivity of additional irrigated land (part of which was pasture rather than cropland) was equal to cropland already in production, and (3) that there were approximately 335 million acres of cropland in 1910. A more detailed estimate of changes in farmland stock is incorporated in the author's unpublished dissertation (6, app. A).

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land stock than would otherwise exist. This in turn would lead to lower product prices than would occur in the absence of Government programs. The irony of this situation is that programs put forward in the name of income transfers to farmers may result in pressures for their continued use because of their unintended impact on the total productivity of the farm sector.

This paper outlines the steps needed in estimating the response landowners would make to policies that affect costs and returns associated with land stock development and improvement. Only if farmer-developer response to specific economic forces is accurately estimated will it be possible to develop efficient farm product price and development policies. If land development response to current product prices and diversion payments is substantial, internally consistent policies would include discontinuation of the various subsidies to development. They would also include either (a) discontinuation of voluntary diversion programs and reliance on a system of marketing quotas or acreage allotments for all major crops, or (b) sufficient reduction of current support prices to discourage any land development which would not take place at free market prices for farm products. Income transfers to farmers could then be made on some basis other than agricultural output and development investment. The current set of policies also have specific interregional and intercrop implications but these are not analyzed in this paper.[5]

Supply and Demand Functions for Farmland Development

The value of land arises from services produced over time. It is the present value of these future services relative to the cost of producing the stock that determines the amount of development that is likely to occur. If the level of returns rises or the period over which returns occur is lengthened, development activity will probably increase. If the costs of developing the stock fall, development activity will probably increase. The problem at hand is to measure the responsiveness of development to a number of economic forces.

In most economic problems the division of the various forces into supply and demand categories has been productive. A capital goods market has some special hazards and analytical peculiarities, but traditional demand and supply concepts are helpful. It is necessary to analyze the entire farm real estate market to understand farmland development.

THE MARKET FOR LAND

At a particular time, the stock of land is fixed and can be altered only through development or abandonment. With a fixed supply the price of land is determined by demand factors. This type of model is known as a reservation demand model.[6] Owners decide whether to sell or to reserve their land for themselves. It is the "offer" curve of the owners and demand curves of would-be owners that are aggregated in constructing the demand curve for land (figure 1).

The characteristics of owners and would-be owners will determine where they are on the reservation demand curve and the distribution of these characteristics will determine the slope of this demand curve. For example, persons with optimistic expectations about future land returns, those with low opportunity costs, and those who receive nonpecuniary income from owning farmland will be on the left portion of the demand curve. Persons with the opposite characteristics will be on the right portion of the demand curve and will be less likely to retain ownership of land or to purchase it. Entering and expanding farmers may be able to reduce annual land costs by buying rather than renting land. Retiring farmers may have relatively high opportunity costs if they wish to transform some of their savings held in real estate into consumption goods. Certainly expectations are not the same for all demanders but they exist relative to a given set of programs and price prospects. Thus, there will be some slope to the reservation demand curve. This slope is of interest because of the role it plays in the demand for land development.

THE DEMAND CURVE FOR NEW LAND

Assume that newly developed land of standard productivity is a perfect substitute for land

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[5] In the presence of programs limiting agricultural output, development of new productive capacity in one region will mean a reduction in employment in another. The interregional impact of development has been dealt with by Back and Jansma (3), Tolley (12), and Howe and Easter (7).

[6] An alternative model of the land market which focuses on the market for the exchange of the stock could be used to develop implications concerning the demand and supply of new land. The exchange market model has been used in analyzing real estate values by Herdt and Cochrane (5), and Reynolds and Timmons (11). The exchange market model is not altogether appropriate for the analysis of new land development because its focus remains on land that is exchanged. Much of the newly developed land is held by the developer for farming purposes. The reservation demand model leads to a new land market in which total development is of interest.

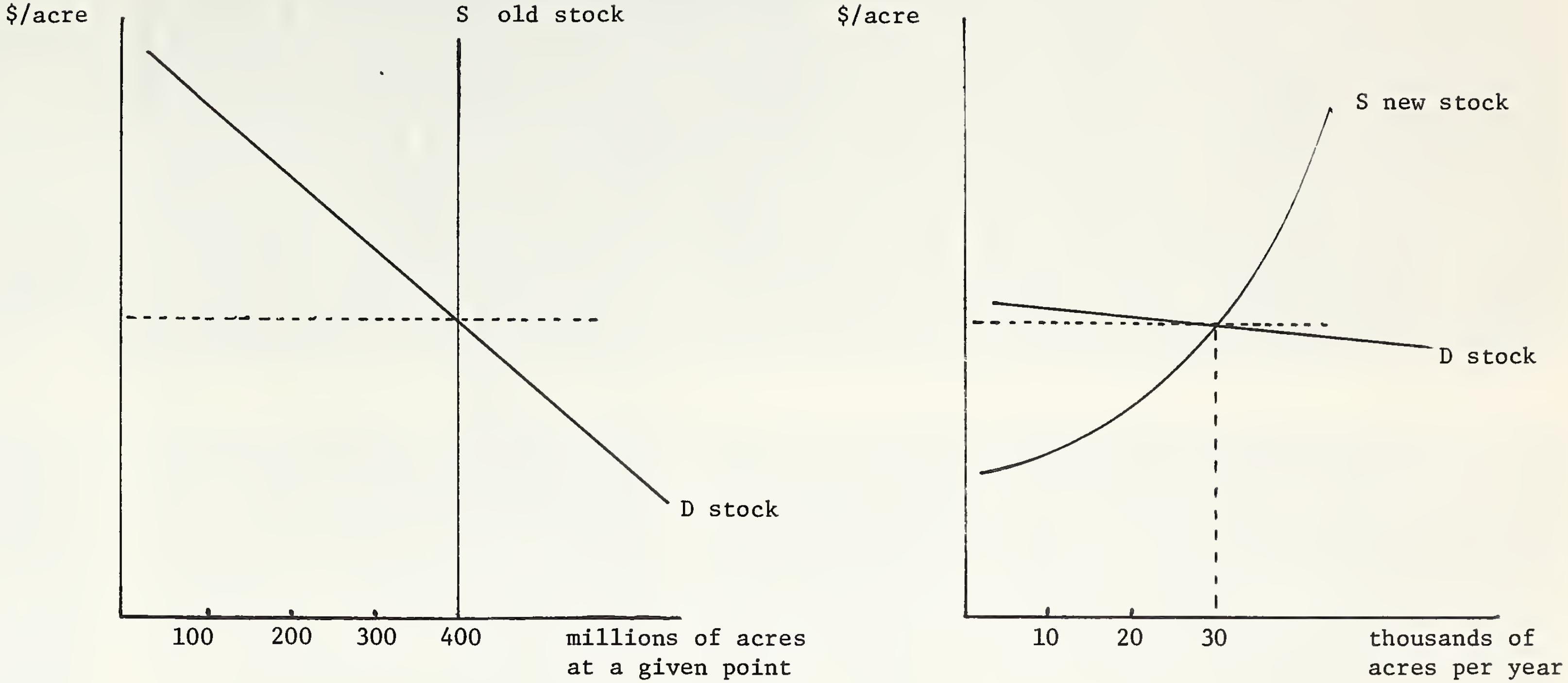

Figure 1. Hypothetical stock and flow markets for agricultural land of standard productivity using the concept of reservation demand

that is already developed. This is equivalent to assuming that farm operating units can be adjusted without cost so that the geographical dispersion of new units of the land is not an element in the demand for land.[7] In this case the demand curve for new land has the same slope as the demand curve for the current stock of land; that is, there is one demand curve that can be viewed in either the "old" or the "new" land market. For most practical considerations this means that the demand for new lands added in any one period is nearly horizontal (figure 1). This follows from the assumptions that the amount of new land in any one time period is very small relative to the amount of developed land and that the demand curve for land is fairly elastic. In the market for new land, then, the level of the demand curve and not its slope will be of prime empirical concern. The determinants of the level of demand will be examined next.

The price a purchaser is willing to pay for land is equal to the present value of its discounted future earnings. The discount factor is subject to change from time to time but outside of changes in the expected rate of inflation, there is little reason to expect sudden and dramatic shifts in the discount rate. On the other hand, changes in the expected annual rate are subject to a number of policy actions. This is where we center our attention.

The annual rent or return to land is a joint function of the production function (or basic productivity of land), the cost of annual inputs, and the price of the product. In recent years, Government price support levels and diversion programs have been a major factor in shaping prices of nearly all farm products, including most of those for which there are no visible price supports. For example, feed grain diversion programs indirectly affect livestock prices. Unsupported crops which have substantial substitution possibilities are also affected by Government programs. Some of the unsupported crops could be grown on land shifted from supported crops. Substitution possibilities are extensive. For example, without a feed grain program of substantial magnitude in the last 8 years, Government stocks of soybeans would have accumulated at the existing support price.

To illustrate the impact of Federal programs on land rent, consider the case in which one product is produced on homogeneous land. Also assume that a Cobb-Douglas production function is an adequate representation of input-output relationships and resulting income distribution. Government policy is to divert land. As the result of an inelastic demand for the product, a larger net rent is paid to land because of the programs. A constant share of larger gross receipts is distributed to fewer acres. Land that is diverted is paid approximately the same amount as land left in production. This source of revenue augments land rent also.

This overly simple model can be applied to U.S. agriculture with the following result. The share (production elasticity in the Cobb-Douglas function) of net income going to land has been about 0.20 in periods of unrestricted production.[8] Net receipts excluding Government payments have recently run about $11 billion but they probably would have been about $9 billion in the absence of restraints on production.[9] In addition to market receipts, payments to producers have recently run to about $3 billion a year. Assume that half of these payments are ascribable to land because they are related to one kind of diversion or another. Rent returns in the absence and in the presence of the programs are estimated in table 1 at $1.8 and $3.7 billion, respectively. The estimate of the absolute value of rent under these assumptions may be in error but under many reasonable assumptions rent would be reduced by half if the programs were suddenly ended.

Because many of the supply-management programs are voluntary, a land developer can obtain part of the benefits of higher land rents arising from higher market prices. The market price of corn, for example, has probably been around $0.25 per bushel above unrestrained market levels (13). On the basis of a budget estimate of recent costs and prices for an assumed yield of 80 bushels per acre, the programs are responsible for about $20 of the approximately $35 rent per acre.[10] This example assumes that no changes occur in the intensity with which other factors are used. If some adjustment in other factor use took place, net rent might not be reduced quite so much. If the farmer-developer could obtain an expansion in the feed grain base on which he can earn direct payments, or if he could obtain a soybean allotment if they are established, the benefits might be even further increased.

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[7] The physical location of the new units of the land stock may affect their value relative to previously developed land. For example, a new unit of land stock developed by closing ditches, increasing row length, etc., may be worth more to a particular farmer than new land developed in a nonfarm area. However, market valuation should operate to make all new land on the margin have approximately the same value per acre as all old land where both are of standard productivity.

[8] Estimated from data for 1938-40 presented by MacEachern and Ruttan (8, p. 208).

[9] Inferred from a prediction by USDA that net farm income would fall $5 billion in the absence of current programs (13).

[10] This budget estimate was derived from (9, p. 8).

A third rent model might be useful. Consider a case in which substantial diversion occurs in a neighborhood experiencing growth in optimum-sized units. Machinery-owning operators are now pitted against each other in the land-rent market. Because laborers and machinery are fixed in the short run, diversion puts considerable pressure on the rental market. Cash rents are bid up or some of the costs traditionally borne by the landlord are shifted to the tenant. As a result, rent responds to diversion as well as to product price.

The three rental examples (models) lead to the same conclusion: Federal government programs affect current real estate returns directly and substantially. The impact of the programs on real estate values is not necessarily as great as on current rents. If the programs are not expected to continue, they may not affect values greatly. Even the most casual observer, however, would conclude that the land market has responded as if Government programs are expected to continue and the benefits of current programs have been capitalized to a substantial degree. A change in Government programs could decisively affect the level of the demand curve for developing lands. With farm product prices consistent with unrestricted production the amount of development could fall substantially and perhaps cease altogether.

THE SUPPLY CURVE OF NEW LAND

If the demand curve for developing lands is very elastic and not shifted in a given period of time, the level and shape of the supply curve for development activity is the primary determinant of the rate of development. If costs are high and increase rapidly with the rate of development, not much development will occur. Alternatively, if costs are low and the supply curve has little slope, a great deal of development will occur.

The supply curve for development for a short to medium run will have an upward slope for several reasons. First, as the rate of development increases, the cost of services used in the activity will probably rise because land clearing and drainage machines and skills are limited in any given local area. In a period of one to five years, a doubling of the desired rate of development would probably bid up factor prices noticeably. In addition, a spurt in the rate of development would probably be

Table 1.--Estimated returns to land assuming a Cobb-Douglas production function with a 20 percent share of net market income [a]

Item	Returns if production were unrestrained	Returns with programs about as in recent years
	Billion dollars	Billion dollars
Net income excluding Government payments:		
Total return	9	11
Return to land	1.8	2.2
Government payments:		
Total return	--	3.0
Return to land	--	1.5
Total income to land	1.8	3.7

[a] Net market income is defined as net farm income less Government payments. Data were selected from various documents to represent recent experience but they do not correspond to any particular year. Defense of the assumption about the share of net market incomes (0.20) and the share of Government payments (0.50) attributed to land may be found in the text.

accompanied by a decline in the efficiency with which inputs are used. The development activity is fairly complex, involving considerable coordination and proper scheduling for lowest costs. Rate of supply has been recognized as a cost factor distinct from volume of supply by Alchian and others. (1)

The other factors that affect the slope of the short-run and intermediate-run supply curve are cost-sharing programs for inputs and tax policy concerning development costs. Cost-sharing by Federal agencies is probably the better known and more important way in which private costs are altered by Government policy. A number of cost-sharing activities have been developed over the years. When some of the costs are paid by a Federal agency, the effective private price for the inputs is reduced and the supply of new lands is shifted to the right. In the instance of Agricultural Conservation Program (ACP) payments, the effective private price is only half the purchase price of the inputs because of the 50 percent cost-sharing arrangement. The impact of Government programs on private prices is very small for activities in which Soil Conservation Service technicians provide technical assistance at no cost to the land developer. For PL-566[11] activities servicing groups of landowners, up to 50 percent of the drainage costs for construction are paid by Federal funds. For flood prevention, in PL-566, 100 percent of the construction costs are federally funded. When PL-566 sponsors are eligible for development loans by Farmers Home Administration, the interest rate is below the private market level.

In the ACP program, the limitation on the amount of cost-sharing per farm permitted each year is fairly restrictive. The cost faced by a given farmer would be low for the portion of work qualifying for cost-sharing, but beyond this basic unit the farmer-developer has to bear all of the cost of development. At that point the supply curve would reflect the full factor cost and would be considerably higher than the earlier work. On each farm the cost curve would be discontinuous at the point at which cost-sharing provisions are exhausted. When the supply curve for all farms is aggregated from individual farm cost curves, the discontinuities would come at different points and the total supply curve would rise if for no other reason than the limit on cost-sharing for the various development activities.

The other way in which the slope and level of the supply curve is affected is through a taxation policy which allows costs incurred in the development process to be charged against current income for tax purposes rather than against the income generated by the investment (2, p. 9). In addition, it is possible for land developers to report some development expenses as if they were current operational expenses.[12] This postpones taxes in the same way as allowable development expense deductions. Assuming, for example, that an investment has a life of 20 years and an 8 percent interest rate is used to discount future income, the present value of the real costs after accounting for the value of taxes postponed may be halved by allowing a present year deduction. As a result the supply curve is shifted to the right.

Even if the short-run supply curve is very inelastic at a particular point the long-run curve would be very elastic (as cost-sharing appropriations are aggregated over time to cover greater acreages). However, the long-run supply curve of newly developed land would be affected by the ease or difficulty of clearing and draining land. Not all land can be cleared with equal ease. The least-cost land would be cleared first. Thus, the long-run supply curve of development probably will be upward sloping even if the cost of factors and the efficiency with which they are used are constant. Other long-run factors include the cost of development inputs which are determined by their alternative uses in industrial activities and the efficiency with which factors can be used in the land development process. Changes in technology are likely to occur which will shift the supply curve of new lands but the magnitude of the shifts cannot be predicted.

SUMMARY OF DEMAND AND SUPPLY FORCES

Usually supply and demand forces jointly determine price and quantity of the good being studied. In the present case expectations of future agricultural earnings determine the price of developed land, which in turn is essentially a perfect substitute for new land. The level of demand is readily observed as the market price for agricultural land. As a consequence the quantity of new land (rate of development) will be the focus of interest in most empirical analyses of land development. This does not mean demand factors can be set aside. It means that land price (excluding allotment values) may be used directly to represent the demand factor rather than resorting to two data series which are less well defined: (1) agricultural price support levels with or without lags to represent expectations, and (2) agricultural or alternative interest rates to represent discount rates. Demand factors will influence the rate and quantity of development but causation runs one way: the price of land influences the quantity of development but the quantity of development does not influence price in the market for new land. As a result a single-equation model can be used rather than the more complicated model in which both quantity and price are determined simultaneously.

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[11] Watershed Protection and Flood Prevention Act.

[12] See, for example, Reinsel (10, p. 27-29), where the USDA estimate of net realized income exceeds Internal Revenue Service net farm profits by a factor of 4 to 1. This divergence in net income arises almost entirely from the IRS system of accounting for expenses. This is necessarily the case because gross receipts reported to IRS are nearly as large as those estimated by USDA.

If cost-sharing and tax allowances are small in the aggregate and evenly distributed among potential land suppliers, the supply curve may be very inelastic in the short run at the point at which cost-sharing benefits and tax allowances are exhausted. This could give rise to a rate of development directly related to Federal benefits. It might lead to a rate which is apparently not responsive to demand considerations on the margin. In such a situation it would be false to conclude that demand forces have no effect on the rate of development. At some level of land prices, new land development would surely drop very close to zero. Thus, an empirical analysis of development could easily lead to an understatement of the importance of demand. Long-run swings in the rate of development might more nearly reflect the importance of demand factors. Even so, if there are long-run shifts in technology which affect the cost per unit of development and if there are limited quantities of the most easily developed acreage the importance of demand factors will be extremely difficult to recognize.

Concluding Comments

Few data are available concerning the size of the farmland stock and its change over time. Consequently, empirical studies in the near future will either be limited in scope or expensive. Nevertheless, studies in this area may have a high social benefit-cost ratio. The failure to develop a refined series of data is at least partially due to the conceptual problems of aggregating acres which have various levels of productivity and which produce different crops. Accounting for changes in fertility, moisture utilization capacity and other characteristics, many of which are steadily affected by the use of nonland inputs, has been an additional impediment to the development of an adequate measure of the land stock.

Uncritical theorizing has been another obstacle to the development of a land stock measure because it has led many to the notion that the stock of land is unalterable except in a downward direction. This theory alone would place emphasis on losses rather than on investment and development activities. The doctrine that the stock can be reduced but not increased would support conservation expenditures beyond levels which are efficient and which are consistent with national public priorities. The same position might lead to an overvaluation of land. Land prices based on population changes might not appear to be out of line so long as they are reinforced by the farm programs (diversion and direct payments) and nominal capital gains. Eventually, however, a revaluation might have cruel redistribution effects on persons who had sunk their life savings in land and who failed to understand the economic forces at work.

In addition to developing studies of recent changes in the stock of land and in the flow of land services, research resources should be invested in the development of appropriate concepts and the required measurements needed to construct and maintain an estimate of the land stock in this country. The development of more adequate concepts could begin with a review of a number of excellent studies sponsored by the USDA and other public groups. Hopefully, this research activity would lead to a continuing measure of the land stock which is similar to the "Conservation Needs Inventory," which is brought up to date at intervals (14). Such a measure would be more difficult to produce than the measure of the growing stock of timber which is updated periodically by the U.S. Forest Service, because productive potential is more difficult to estimate than is the current volume of growth of a particular class of plants. The land stock measure would have to deal with measures of nonland investments incorporated in land as well as physical surfaces. Even though the problems are formidable, the potential returns are substantial.

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The Demand for Fertilizer, 1949-64: An Analysis of Coefficients From Periodic Cross Sections

By Gordon C. Rausser and Theo. F. Moriak

Econometric studies of the demand for farm inputs have accumulated large amounts of quantitative information in recent years. The usefulness of this information for various policy purposes, however, is questionable, since most of these studies have assumed that input demand coefficients have remained constant over time. The relaxation of this assumption should prove useful by allowing decision makers to take explicit account of the way in which demand coefficients are changing over time.

This analysis deals with the demand for a particular input, fertilizer, with major emphasis on analyzing the variations in demand coefficients by means of periodic cross-section data at the State level. A number of previous studies (2, 4)[1] based on time-series data have provided estimates of the demand for fertilizer, assuming the coefficients to be constant over the period we propose to investigate. A study by Griliches (3) was concerned with similar estimation based on cross-section data for a single year, 1954. The Griliches study provides the foundation for our article.

More specifically, our objectives are:

(1) To ascertain whether fertilizer demand coefficients based on cross-section data have remained constant over time.

(2) To determine whether any useful information is revealed by introducing dynamic and stochastic considerations. For example, does the long-run demand for fertilizer, based on static assumptions, differ from the long-run demand based on dynamic assumptions? Are the results substantially the same if coefficients of explanatory variables are assumed subject to random variation rather than constant?

(3) To determine whether introduction of variables signifying shifts for State or regional classifications and several cross-sections over time alter a previous conclusion by Griliches (3, p. 383) that a dynamic adjustment model may "not represent a very useful approach to cross-sectional data." Griliches suggests that a more useful approach than simply introducing a lagged value of the dependent variable 5 years earlier (an approach he employed) might consist of employing several cross sections and allowing dummy variables for each State.

Changes in Fertilizer Use

Fertilizer use in the United States has increased dramatically in recent years. For example, the use of the three principal plant nutrients--nitrogen, phosphoric acid, and potash--which either individually or in combination make up fertilizer "tripled between 1950 and 1965" (10, p. 1). Although the increase in magnitude for these three nutrients has been about the same, the use of nitrogen and potash has increased relative to the use of phosphoric acid (2, p. 595). At the same time, the average plant nutrient content of fertilizer rose from .20 in the earlier 1940's to .36 in 1965.

In contrast to other farm inputs, the price of fertilizer has not increased in recent years. In fact, as Griliches points out, the "real" price of fertilizer, measured as the price of a plant nutrient unit relative to the price received for all crops, "fell by 50 percent between 1940 and 1950" (2, p. 595). Moreover, there was a modest downward trend of this price from 1950 through 1964.

In addition to these changes at the aggregate U.S. level, there also exists a substantial range among States in the nutrient content of fertilizer, the proportion in which nutrients are consumed, and the levels of fertilizer use from State to State (3). Similarly, the pattern of fertilizer use has shifted considerably over major regions of the United States from 1945 to 1967. Pounds of fertilizer consumed per acre rose rapidly in the West North Central region and moderately in the East North Central, West South Central, Mountain, and Pacific regions, and fell rapidly in the New England, Middle Atlantic, South Atlantic, and East South Central regions.

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[1] Underscored numbers in parentheses indicate items in the References, p. 56.

Data Models And Procedures

The specified form of the basic economic model is similar to Griliches' model (3) and the statistical model was confirmed by inspecting the original data with the aid of scatter diagrams. The basic form of the model is:

$$(1) \qquad Y = X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3}$$

where Y = pounds of principal plant nutrient consumed per acre; X_1 = "real" price of fertilizer, i.e., price paid per plant nutrient unit relative to average value of crops produced per acre; X_2 = price of fertilizer relative to the average cash wage paid per day to hired farmworkers; and X_3 = price of fertilizer relative to average cash rent paid per acre. Thus, fertilizer use is treated as a function which is linear in logarithms of the price paid for fertilizer, the prices received for farm products, and prices paid for two other major inputs--labor and land.

Such a function is implied by a Cobb-Douglas production function between farm output and fertilizer, land, and labor, as well as profit maximization by individual farmers. Therefore, equation (1) may be regarded as the reduced form of the fertilizer demand equation resulting from a structural form which simultaneously determines output and levels of the various inputs.[2]

The data employed to estimate the various alternative formulations of equation (1) are cross-sectional from the 48 contiguous States for the years 1949, 1954, 1959, and 1964. Therefore, for observation i in year j, equation (1) becomes:

$$(2) \qquad Y_{ij} = X_{1ij}^{\beta_{1j}} X_{2ij}^{\beta_{2j}} X_{3ij}^{\beta_{3j}}$$

where i = 1, . . ., 48, denotes the contiguous States, and j = 1949, 1954, 1959, and 1964, denotes years for which cross-sectional data are utilized. Cross-sectional rather than time-series data were utilized because it was not feasible to assess the contribution of input prices (other than fertilizer prices) on fertilizer consumption for the latter data. In contrast, cross-sectional data allowed us to isolate the impact of other important input prices in addition to the real price of fertilizer.

Three measures of the variables included in equation (2) are employed in our analysis. These are pounds of principal plant nutrient used per acre or cropland harvested (Y); pounds of principal plant nutrient used per acre of cropland harvested and improved pasture (Y'); and pounds of principal plant nutrient, adjusted for the change in nutrient content by a price-weighted relationship used per acre of cropland harvested and improved pasture (Y'').[3]

Four basic formulations of the econometric models implied by equation (2) are estimated, each based on alternative assumptions. The first two employ the traditional assumptions of constant coefficients at a given point in time for successive observations across States. The first model, which we call the nonrandom static model, may be represented as:

$$(3) \qquad y_j = \beta_{1j}x_{1j} + \beta_{2j}x_{2j} + \beta_{3j}x3_j + \mu_j$$

where j = 1949, 1954, 1959, 1964 and the lowercase letters denote the logarithms of the variables in equation (2). To ascertain whether the coefficients of this model are constant over time, we formulated the following null hypothesis:

$$H_o^s : \beta_{49} = \beta_{54} = \beta_{59} = \beta_{64} = \beta$$

where $\beta_j' = (\beta_{1j}\ \beta_{2j}\ \beta_{3j})$ and $\beta' = (\beta_1 \beta_2 \beta_3)$.

The statistical model based on H_o^s may be stated as:

$$(3.a) \qquad Y = X\beta + U^{so}$$

where

$$Y' = (Y_{49}\ Y_{54}\ Y_{59}\ Y_{64}),$$

$$X' = (X_{49}\ X_{54}\ X_{59}\ X_{64}),$$

$$X_j = (X_{1j}\ X_{2j}\ X_{3j}), \text{ and}$$

$$U^{so\,\prime} = \left(U_{49}^{so}\ U_{54}^{so}\ U_{59}^{so}\ U_{64}^{so}\right)$$

denotes the vector of stochastic terms under the null hypothesis. Each element is assumed to be normally distributed, more precisely $U^{so}_{ij} \sim N(0,\sigma^2_{so})$.

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[2] Although the problem of simultaneous determination of the variables in the proposed model exists, it does not appear to be of major importance in the case of fertilizer demand. Griliches (2, p. 601) suggests that since fertilizer prices are largely "administered prices" and since prices of output and inputs may be regarded as predetermined in the fertilizer decision, the simultaneous interaction may be ignored. For a treatment of the interaction between output and various inputs, see Malinvaud (7, pp. 517-520).

[3] A paper providing a detailed discussion of the transformations, raw data sources, and comparisons of the data series, as well as a more complete development of the various econometric models estimated, will be supplied by the authors upon request.

A more general specification would suggest that $B_{j'} \neq B_j (j' \neq j)$. Under this alternative hypothesis, the coefficients are allowed to vary from one cross-section to another. More precisely,

$$H^s_a : \beta_{49} \neq \beta_{54} \neq \beta_{59} \neq \beta_{64}$$

and the corresponding model is:

$$Y = X^* \beta^* + U^{sa}$$

where X^* denotes a diagonal matrix of which each nonzero element is

$$X_j,\ \beta^* = (\beta_{49}\ \beta_{54}\ \beta_{59}\ \beta_{64}), \text{ and}$$

$$U^{sa} = (U^{sa}_{49}\ U^{sa}_{54}\ U^{sa}_{59}\ U^{sa}_{64})$$

denotes the vector of stochastic terms under the alternative hypothesis. Each element is assumed to be normally distributed.

Coefficients are estimated under the null hypothesis as a pooled regression and the alternative hypothesis as separate regressions for each census year by ordinary least squares. This was done for the three measures: Y, Y', and Y''.

The test employed to determine whether the coefficients (elasticities) are constant over the years considered is based on an F-statistic. It is calculated as:

$$F = \frac{\hat{U}^{so'}\hat{U}^{so} - \hat{U}^{sa'}\hat{U}^{sa}/(df_{so} - df_{sa})}{\hat{U}^{sa'}\hat{U}^{sa}/df_{sa}}$$

where df_{so} and df_{sa} denote the degrees of freedom under the null and alternative hypothesis, respectively.

Another formulation of the static model introduced an intercept coefficient and allowed its value to vary over States. This was accomplished by introducing dummy variables into the models resulting from the null and alternative hypotheses. In estimating such models, we found that although many of the dummy variable coefficients for individual States are significant, they tend to group around certain specific values. Thus, it seems reasonable to employ regional dummy variables which have the added advantage of summarizing information from a group of States with fewer coefficients.

For this formulation, nine regions were utilized to group various States.[4] Such a regional definition was found to be generally consistent with the grouping pattern of the individual State dummy variable formulation. The resulting intercept coefficient over time is estimated as:

$$\text{(3.c)} \qquad Y = X^*\beta^* + D\delta + U^{sr}$$

where D denotes a 4x9 matrix of dummy variables, each element

$$D_{jr} = \begin{Bmatrix} 1, \text{ if the observation (State)} \\ \quad \text{is in the rth region} \\ 0, \text{ otherwise} \end{Bmatrix}, \text{ for all } j;$$

$$\delta' = (\delta_1, \ldots, \delta_9)$$

denotes the respective regional dummy coefficients; and

$$U^{sr'} = (U^{sr}_{49}\ U^{sr}_{54}\ U^{sr}_{59}\ U^{sr}_{64})$$

denotes the vector of stochastic terms under the static specification employing regional dummies. Each element is assumed to be normally distributed.

The second model is a simple dynamic version of equation (3) employed by Griliches (3) and is referred to here as the nonrandom dynamic model, its form is

$$y_j = \lambda_j\beta_{1j}x_{1j} + \lambda_j\beta_{2j}x_{2j} + \lambda_j\beta_{3j}x_{3j} + (1-\lambda_j)y_{j-5} + \lambda_j\mu_j \ .$$

The difference between these two models is simply that for the latter, λ_j (defined as the adjustment coefficient) is allowed to assume values other than 1. Moreover, the formulation in (3) interprets the interstate differences in plant nutrient use as "representing an adjustment to long-run differences in relative prices" (3, p. 377), while formulation (4) recognizes the possibility that interstate differentials may also reflect short-run considerations.

The derivation for equation (4) is based on the "partial adjustment" model. The basic premise is that an adjustment to a disequilibrium situation is not instantaneous. There presumably exists some sort of adjustment cost, such as a cost of being out of equilibrium or a cost of change which justifies the observed inertia in the responsiveness of farmers to relative input prices, i.e., $y_t^* = f(x_t)$. That adjustment during a period of time is a function of the difference between the desired and the actual level of consumption, i.e.,

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[4] As defined in Agricultural Statistics (11), these regions are: Region 1–New England; Region 2–Middle Atlantic; Region 3–East North Central; Region 4–West North Central; Region 5–South Atlantic; Region 6–East South Central; Region 7–West South Central; Region 8–Mountain; and Region 9–Pacific.

$$y_t - y_{t-1} = \lambda(y_t^* - y_{t-1}).$$

Substituting the first equation into the second and solving for y_t, we have

$$y_t = \lambda f(x_t) + (1 - \lambda) y_{t-1}$$

which is nothing more than an alternative representation of (4). However, note that in (4) a 5-year lag is assumed. This is the result of having comparable data only at 5-year intervals and the lack of any substantial changes in cross-sectional differentials for 1-year periods.

Procedures similar to those employed in the case of the nonrandom static model are utilized to ascertain whether all coefficients, including the adjustment coefficient, are constant over time. However, here 1949 is omitted, since including the lagged dependent variable representing 1944 (a war year) might be expected to involve considerable structural changes. The relevant null hypothesis, therefore, is:

$$H_o^d: \begin{bmatrix} \lambda\beta \\ 1-\lambda \end{bmatrix}_{54} = \begin{bmatrix} \lambda\beta \\ 1-\lambda \end{bmatrix}_{59} = \begin{bmatrix} \lambda\beta \\ 1-\lambda \end{bmatrix}_{64} = \begin{bmatrix} \lambda\beta \\ 1-\lambda \end{bmatrix}$$

and the corresponding model is designated as (4.a). The general specification for the dynamic case follows from the alternative hypothesis in which all coefficients vary among years, i.e.,

$$H_a^d: \begin{bmatrix} \lambda\beta \\ 1-\lambda \end{bmatrix}_{54} \neq \begin{bmatrix} \lambda\beta \\ 1-\lambda \end{bmatrix}_{59} \neq \begin{bmatrix} \lambda\beta \\ 1-\lambda \end{bmatrix}_{64},$$

and the model accordingly is designated (4.b).

In addition to the above specifications, a dummy variable formulation of the nonrandom dynamic model was introduced which is operationally equivalent to (3.c) except that $\lambda_j \neq 1$, for all j. This specification employs the same regional dummy variables as (3.c) and is referred to as (4.c).

The second two models are based on the same distinction between static and dynamic but assume that the coefficients are subject to random variation. They are referred to as the random static and random dynamic models. The rationale for such an assumption has been fairly well outlined by Hildreth and Houck (5, p. 584) for the general case. For the case here, response of fertilizer use to relative prices depends on a number of factors in a given State such as soil types, climatic conditions, crops grown; natural stocks of nutrients in the soils; amount of capital possessed by, or available to, farmers; and type of land tenure. Unfortunately, these factors cannot always be observed and, when they are, they cannot be conveniently included in regression models. However, since these factors do vary across States and over time and are unobserved, it seems reasonable, as an alternative formulation to (3) and (4), to regard the coefficients as the mean of a random coefficient (elasticity). Thus, formulations (3) and (4) become:

$$(5) \quad y_{ij} = (b_{1j} + v_{1ij})x_{1ij} + (b_{2j} + v_{2ij})x_{2ij} + (b_{3j} + v_{3ij})x_{3ij}$$

$$(6) \quad y_{ij} = \lambda_j(b_{1j} + v_{1ij})x_{1ij} + \lambda_j(b_{2j} + v_{2ij})x_{2ij} + \lambda_j(b_{3j} + v_{3ij})x_{3ij} + (1-\lambda_j)y_{ij-5}$$

where i, j are as defined previously; b_{kj} denotes the mean response of fertilizer consumption to a unit change in the kth independent variable, k = 1, 2, 3; and v_{kij} denotes independently and identically distributed random errors with zero means. For these formulations, the actual response is $(b_{kj} + v_{kij})$ for the i, jth observation.

The procedures employed to estimate the unknown parameters of these two models require some further elaboration. Considering the random static formulation, to determine the mean response (elasticity) of fertilizer consumption to a unit change in one of the independent variables we reformulate (5) as:

$$(5') \quad y_{ij} = b_{1j}x_{1ij} + b_{2i}x_{2ij} + b_{3i}x_{3ij} + \omega_{ij}$$

where

$$\omega_{ij} = \sum_{k=1}^{3} x_{kij} v_{kij};$$

i, j as defined previously. The b_{kj} are the mean elasticities and v_{kij} are the unobserved random disturbances with zero means.

More precisely, the v_{ki} are assumed to be independently and identically distributed with variance

$$E(v_{ki})^2 = \alpha_{kk}.$$

Moreover, for any i', i and k' $\neq$ k, it is assumed that $v_{k'i'}$ is independent of v_{ki}. Thus, for any given j, the variance-covariance matrix of ω_j, $E(\omega_j\omega_j') = \theta$, is composed of $\theta_{i'i} = 0$, $i' \neq i$ and

$$\theta_{ii} = \sum_{k=1}^{3} x_{ik}^{2} \alpha_{kk} = \dot{x}_{(t)} \alpha,$$

where $\dot{x}$ is a 48 x 3 matrix whose elements are the squares of the corresponding elements of x, $\dot{x}_{(t)}$ is the tth row of $\dot{x}$, and α is a column vector with elements $\alpha_k = \alpha_{kk}$, k = 1, 2, 3. This development follows from Hildreth and Houck (5, pp. 585-589).

There are a number of consistent estimators of the unknown parameters of formulation (5'). Rao (8) has considered related models, and Rubin (9) has derived maximum likelihood estimators for model (5'). Because of the complexities of programming Rubin's estimators, we have utilized a less sophisticated consistent estimator suggested by Hildreth and Houck (5). The estimator is:

$$b = (x' \, \hat{\theta}^{-1} x)^{-1} x' \, \hat{\theta}^{-1} y \tag{7}$$

where $\hat{\theta}$ denotes a diagonal matrix which is an estimate of the variance covariance matrix of ω. The elements of the diagonal are given by:

$$\hat{\theta} e = \dot{x}\hat{\alpha} \tag{8}$$

where e denotes a T column vector, the transpose of which is 1,1, ..., 1), and $\dot{x}$ denotes a matrix whose elements are the squares of the corresponding elements of x.

The estimator, $\hat{\alpha}$, was adopted after consideration of three estimators, all of which are consistent. This estimator is derived by applying restricted least squares to a regression problem where the unknown parameters are the values of $\hat{\alpha}_k$. This is a simple quadratic programming problem (6, pp. 170-172) which selects the vector $\hat{\alpha}$ that minimizes the sum of squared errors subject to the condition that the elements of $\hat{\alpha}$ be nonnegative.

The basic approach to the derivation of equation (7) follows from generalized least squares (7, pp. 149-153), where α and thus θ are unknown. That is, the procedure is first to derive a consistent estimate of α by quadratic programming and utilize these estimates in equation (8) to derive the diagonal elements of θ which, in turn, are utilized in equation (7) to estimate the vector $\hat{b}$.

The same estimator employed for formulation (5') is utilized for model (6) which is similarly rearranged as

$$y_{ij} = \lambda_j b_{1j} x_{1ij} + \lambda_j b_{2j} x_{2ij} + \lambda_j b_{3j} x_{3ij} + (1-\lambda_j) y_{ij-5} + \lambda_j \omega_{ij}. \tag{6'}$$

As before, the essential difference between the two models is that for (5') we estimate the mean elasticities under the assumption that $\lambda_j = 1$, for all j, while for formulation (6'), we impose the estimates derived from the nonrandom dynamic model. Moreover, for each of the two random models, we estimate the coefficients under both the null and alternative hypotheses. In the case of the random static model, the equation corresponding to the null hypothesis is designated (5.a') while the equation corresponding to the alternative hypothesis is designated (5.b'); similarly, for the random dynamic model, the designations are (6.a) and (6.b').

In the following section, we present the estimates for each of these four basic models and a test of the hypothesis that the coefficients, estimated for formulations (3) and (4), are constant over the period for which we have cross-sectional data.

Empirical Results

NONRANDOM STATIC MODEL

In table 1, the results for the three different measures of the variables are reported under the null hypothesis, while only the results for the weighted price measure (Y' ') are reported under the alternative hypothesis. In the case of Y' ', F = 7.15 and is significant at the .05 level. Therefore, the null hypothesis, H_0^S, is rejected. For all three measurements, we come to the identical conclusion that the elasticities vary from one cross section to another. Least-squares estimates of the parameters give the expected signs regardless of the measurements employed. Although there is close statistical correspondence between all three measures, we select Y' ' for all further investigation since it accounts for changes in fertilizer nutrient content and, thus, provides a more intuitively appealing measure of plant nutrients used per acre. Note that the estimates conform to the intuitive notion that labor is a complement to and land is a substitute for fertilizer since the cross elasticity for labor ($-\hat{\beta}_{1j}$) is negative and the cross elasticity for land ($-\hat{\beta}_{3j}$) is positive.

Further examination indicates that a major portion of the interstate variation represented by each series is explained by a few simple economic variables (high R^2). The standard errors of the estimates are low and all estimates are highly significant. It is clear that the absolute value of all coefficients trends downward over the period of investigation implying that fertilizer use per acre has become less responsive to relative changes in other input prices and crop value per acre. For example, in 1949, a 10-percent increase in crop value was associated with approximately an 8.9-percent increase in fertilizer use; a 10-percent increase in the price of labor was associated with approximately a 14.3-percent decrease in fertilizer; a 10-percent increase in the price of land services was associated with approximately a 10.4 percent increase in fertilizer use. In contrast, in 1964, the corresponding responses of fertilizer use to 10-percent increases in the variables referred to above are, respectively, a 6.2-percent increase, a 4.2-percent decrease, and a 5.1-percent increase.

In an attempt to shed further light on the parameter changes we tested to determine if all coefficients for each 2 successive years were stable. In each case, the null hypothesis of no parameter change could not be rejected. Thus, an isolation of parameter shifts between any successive census years was not possible.

Note, however, that fertilizer use has become more responsive to its own price over the same period. For example, in 1949, a 10-percent increase in the price of fertilizer led to approximately a 5-percent $[(-.891+1.427-1.038)*10]$ decrease in fertilizer use, while a similar increase in 1964 resulted in approximately a 7-percent $[(-.620 + .421 - .505)* 10]$ decrease in fertilizer use.

The inference that fertilizer use is responsive to its own price is based on reformulating (3) as

$$\ln Y_j = (\hat{\beta}_{1j} + \hat{\beta}_{2j} + \hat{\beta}_{3j}) \ln P^f_j -$$

$$\hat{\beta}_{1j} \ln V_j - \hat{\beta}_{2j} \ln P^w_j - \hat{\beta}_{3j} \ln P^r_j$$

where

$$X_{ij} = \frac{P^f_j}{V_j},\ X_{2j} = \frac{P^f_j}{P^w_j},\ \text{and } X_{3j} = \frac{P^f_j}{P^r_j},$$

and X_{kj} are as defined on p. 46, which implies that the sum of the estimated coefficients is the elasticity of fertilizer demand with respect to fertilizer price (P^f_j).

The regional dummy variable specification (3.c) in table 1 is reported here only for the formulation which allows intercept coefficients to vary across regions and elasticities to vary over time. This is the result of little additional information (i.e., insignificant) being provided by alternative designations where intercept coefficients vary over time as well as across regions for both stable and varying elasticities.

The results of this formulation may be regarded as superior to those of (3.a) or (3.b). Table 1 reveals that all β_{kj}(k = 1, 2, 3; j = 1949, . . ., 1964) coefficients are significant at the 5-percent level and lower in absolute value than the corresponding estimates for model (3.b). The reduction in these estimates is the result of including previously omitted variables which, for five of the nine regions, are significant at the 5-percent level. Moreover, as indicated by the F value of 18.5, the set of regional dummy variables is highly significant. This F value provides a test of the null hypothesis $\delta = (\delta_1 \ldots \delta_9) = (0 \ldots 0)$ against the alternative hypothesis $\delta = (\delta_1 \ldots \delta_9) \neq (0 \ldots 0)$ and implies that the former should be rejected in favor of the latter. Note also that the measure of fit provided by the value R^2 is considerably higher than the similar measure for the previous model. Thus, it appears the inclusion of regional dummy variables adequatly summarizes the effects of States (grouped) on the amount of fertilizer used per acre.

Considering the values of the regional dummy coefficients, it is clear that the New England States (region 1) and Middle Atlantic States (region 2) have had the largest impact on U.S. fertilizer demand. A probable explanation lies in the intensive farming in these regions as well as their general acceptance of fertilizer practices. The South Atlantic States (region 5) are quite close to those mentioned above in their effect on demand; this may be due in part to the considerable amounts of fertilizer required for tobacco production. In contrast, the Mountain States (region 8) show the smallest impact on demand, which is most likely explained by the region's extensive farming in such enterprises as grains and range feeding of cattle. The values of the dummy variable coefficients for the other regions fall between those discussed above and similarly may be explained on the basis of the crops and types of farming found in such areas.

NONRANDOM DYNAMIC MODEL

Tests of the null hypothesis regarding stable slope and adjustment coefficients for the nonrandom dynamic model are shown in table 2 and indicate that it should be rejected at the .05 level of significance. In all regressions,

Table 1.--Nonrandom static models

Eq. no.	Dependent variable	N	Year	Coefficients of[a/] X_{1j}	X_{2j}	X_{3j}	R^2	F
3.a	Y (.071)	192	49-64	-.747* (.059)	.830* (.077)	- .728* (.070)	.735	6.94*
3.a	Y' (.063)	192	49-64	-.673* (.057)	.820* (.074)	- .807* (.067)	.748	6.00*
3.a	Y'' (.067)	192	49-64	-.693* (.056)	.817* (.072)	- .770* (.068)	.742	7.15*
3.b	Y'' (.089)	48	49	-.891* (.148)	1.427* (.199)	-1.038* (.180)	.708	
3.b	Y'' (.053)	48	54	-.733* (.090)	.913* (.117)	- .786* (.112)	.811	
3.b	Y'' (.045)	48	59	-.663* (.077)	.654* (.095)	- .666* (.093)	.820	
3.b	Y'' (.035)	48	64	-.620* (.059)	.421* (.073)	- .505* (.069)	.856	
3.c	Y'' (.043)	192	49	-.816* (.079)	1.284* (.177)	- .720* (.097)	.904	
			54	-.704* (.081)	.751* (.172)	- .408* (.100)		
			59	-.605* (.082)	.467* (.160)	- .321* (.100)		
			64	-.522* (.080)	.183 (.155)	- .181** (.096)		

Eq. no.	Regional dummy variables 1	2	3	4	5	6	7	8	9	F
3.c	1.50* (.58)	1.42* (.58)	1.15* (.58)	.41 (.60)	1.40* (.53)	1.09* (.52)	.41 (.57)	.30 (.60)	.65 (.63)	18.5*

a/ Coefficients significantly different from zero at the 5-percent level are denoted by *; those at the 10-percent level by **. Standard errors of the estimates are reported in parentheses.

Table 2.--Nonrandom dynamic models

Eq. no.	Dependent variable	N	Year	Coefficients of[a/]				λ	R^2	F
				X_{1j}	X_{2j}	X_{3j}	Y_{j-5}			
4.a	Y'' (.021)	144	54-64	-.220* (.028)	.043 (.036)	-.154* (.032)	.609* (.025)	.391	.962	3.59*
4.b	Y'' (.023)	48	54	-.289* (.050)	.096 (.077)	-.152* (.066)	.563* (.040)	.437	.966	
4.b	Y'' (.018)	48	59	-.062 (.048)	-.119** (.061)	-.015 (.055)	.826* (.052)	.174	.973	
4.b	Y'' (.019)	48	64	-.118* (.058)	-.056 (.060)	-.128* (.052)	.695* (.066)	.305	.958	
				Long-run coefficients						
4.a	Y''	144	54-64	-.567	.111	-.397				
4.b	Y''	48	54	-.661	.220	-.348				
4.b	Y''	48	59	-.356	-.684	-.086				
4.b	Y''	48	64	-.387	-.184	-.420				
4.c	Y'' (.020)	144	54	-.344* (.049)	.176 (.118)	-.122* (.059)	.535* (.041)	.465	.972	
			59	-.131* (.061)	-.045 (.117)	.022 (.059)	.784* (.068)	.216		
			64	-.179* (.066)	-.002 (.111)	-.083 (.059)	.652* (.079)	.348		

Regional dummy variables									
1	2	3	4	5	6	7	8	9	F
.235 (.410)	.203 (.405)	.302 (.406)	.270 (.418)	.222 (.375)	.206 (.361)	.070 (.402)	.090 (.427)	.179 (.438)	1.24

Long-run coefficients		
-.740	.378	-.262
-.606	-.208	.102
-.514	-.005	-.239

[a/] Coefficients significantly different from zero at the 5-percent level are denoted by *. Standard errors of the estimates are reported in parentheses.

the introduction of the lagged dependent variable reduces both the absolute size and the statistical significance of all other coefficients. The decrease in absolute size is expected, since the nonrandom dynamic model treats these coefficients as short-run coefficients, while the previous static model assumes that the corresponding coefficients reflect primarily long-run considerations.

The reduction in statistical significance and the wrong signs on the estimates, in some cases, are more difficult to explain. The most reasonable explanation appears to be multicollinearity. Y_{j-5} is highly correlated with X_{1j} and X_{3j} and moderately correlated with X_{2j}. Thus, it is likely that the variance of the estimates relative to the value of the estimates is high, resulting in insignificant t-tests for the coefficients but, nonetheless, increasing values of R^2. Moreover, Y_{j-5} is clearly the dominant variable for all regressions of the nonrandom dynamic model and most likely "robs" from X_{1j}, X_{2j}, and X_{3j} in the explanation of interstate variation in fertilizer use per acre. This possibility is supported by the rather high estimated correlation between the estimates of $\lambda_j\beta_{kj}$, and $1-\lambda_j$, $k = 1, 2, 3$. These values are in the neighborhood of .4 to .7, with the highest values occurring between $\lambda_j\beta_{2j}$ and $1-\lambda_j$. Thus, it seems reasonable to suggest that our estimates of $\lambda_j\beta_{kj}$, $k = 1, 2, 3$, are biased downward and our estimates of $1-\lambda_j$ are biased upward. This implies that the estimates of the adjustment coefficients, λ_j, are biased downward.

The above discussion also partially explains the long-run coefficients (β_{kj}) shown in table 2, provided the degree of underestimation of $\lambda_j\beta_{kj}$, $k = 1, 2, 3$, and λ_j is not the same. If the relative underestimation were the same, then estimates of the long-run coefficients are unbiased. This follows, since the estimate of the various long-run coefficients is simply

$$\frac{\lambda_j\beta_{kj}}{1-(1-{}_j)}.$$

However, if the relative underestimation of $\lambda_j\beta_{kj}$, $k = 1, 2, 3$, is greater than the relative underestimation of λ_j, then estimates of the long-run coefficients are biased downward. This appears to be the case, since estimates of the long-run coefficients for the dynamic model are smaller (in absolute terms) than estimates resulting from the static model under both the null and the alternative hypotheses. These differences, in some cases, are small (e.g., 1954 estimates of $\beta_{1,54}$) and may not be statistically significant, but for other estimates (particularly all estimates of β_{3j}), it would appear that either the magnitude of underestimation of the long-run coefficients is large or that the original reason for introducing Y_{j-5} was not valid.[5] That is, cross-sectional differences reflect adequately long-run differentials in fertilizer consumption, and the dynamic model may "not represent a useful approach to cross-section data" (3, p. 383). Note, however, as we would expect, the implied long-run coefficient of the price of fertilizer (sum of the coefficients on X_{1j}, X_{2j}, X_{3j}) is considerably larger than the corresponding coefficients for the static formulation (1954: -789 vs. -.502; 1959: -1.126 vs. -.606; 1964: -.991 vs. -.704). A decision on the adequacy of the "adjustment model" must await the empirical results of other models examined in this paper.[6]

As in the case of (3.c), the results for the dummy variable formulation of the dynamic model are reported in the bottom portion of table 2 only for the specification which allows intercept coefficients to vary across regions and elasticities to vary over time. The justification is the equivalent to that noted in the discussion of the empirical results for (3.c).

As shown in table 2, all coefficients of the regional dummy variables are roughly one-half their standard errors and thus insignificant. However, the presence of the lagged dependent variable confounds the separation of the individual regional effects from the effect induced by the lagged variable. The problem, as before, is that the lagged fertilizer use variable appears to reflect too much and thus reduces the coefficients of the dummy variables to too low a level. It also renders the set of dummy variables insignificant as indicated by the calculated F value of 1.24.

In any case, it is worth noting that the long-run coefficients for X_{1j} implied by this model (4.c) are generally equivalent to those given in table 1 for the static regional dummy variable model (3.c).

RANDOM MODELS

The results for the random static model are reported in table 3 under the null hypothesis (5.a') that the mean coefficients are constant and under the alternative hypothesis (5.b') that the mean coefficients vary from one cross-section to another. However, for this model and its dynamic version, a test of the null hypothesis is not provided, since the distribution properties of the estimator employed have not been determined (5, pp. 590-591). As in the case of (3.b), the (absolute) percentage mean response of fertilizer consumption to percentage changes in fertilizer price, crop value per acre, farm wages, and price of land services trended downward from 1949 to 1964. This again leads to the conclusion that fertilizer consumption, over the period of investigation, has become less responsive to relative changes in input prices and output price. More specifically, the estimators calculated from the quadratic programming formulation are quite similar to the corresponding nonrandom estimates (table 1) and show in 1949 a 10-percent increase in the farm wage rate being associated with a mean 14.6-percent decrease in plant nutrients used per acre; whereas, in 1964, a similar increase in the farm wage rate resulted in only a mean 4.4-percent decrease in fertilizer consumption per acre. Similar movements of smaller magnitude are associated with price of land, crop value, and fertilizer prices.

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[5] This discussion is based on the usual assumption that long-run elasticities are larger than the corresponding short-run elasticities.

[6] Tests to determine if the adjustment coefficients have been constant, while the elasticities have changed and vice versa resulted in rejection in favor of the alternative hypothesis (4.b). Thus, little information can be gained from more restrictive specifications than (4.b).

The values of the estimators for the random dynamic model are reported in the bottom portion of table 3. For the null hypothesis (6.a'), the nonrandom dynamic estimate, i.e., $\lambda_{54-64} = .391$ is imposed while for the alternative hypothesis, estimates from formulation (4.b) are imposed, i.e., $\lambda_{54} = .437$, $\lambda_{59} = .174$, and $\lambda_{64} = .305$ (see table 2). In comparing the quadratic program estimates to those of the nonrandom dynamic model (table 2), we find the estimated values (absolute) of the former to be generally higher. However, these random estimates suffer from the same difficulties as the nonrandom dynamic estimates. The correspondence between the long-run coefficients implied by the random static model and the random dynamic model is slightly better than correspondence between the nonrandom static (table 1) and the nonrandom dynamic (table 2) long-run coefficients (i.e., the differences between the two sets of estimates are generally smaller for random models). The difference in correspondence, however, can hardly be considered overwhelming.

Conclusion

The above results indicate that, for both the static and dynamic formulations of the demand for fertilizer, coefficients based on cross-sectional data have not remained constant over time. In fact, the coefficients consistently trend downward (absolutely) throughout the period of investigation. The static model estimated a 30-percent decline in the fertilizer-output price elasticity and a 51-percent decline in the fertilizer-land input price elasticity in 1949. Similarly, the dynamic model estimated declines of 59 percent, 41 percent, and 16 percent for the same elasticities from 1954 to 1964. Therefore, we conclude that fertilizer consumption per acre has become less responsive to changes in relative prices. One possible explanation is that fertilizer use has become an accepted practice, implying that farmers who employ fertilizer are less receptive to relative price changes. A further possible explanation with regard to the fertilizer-output price ratio is that farmers are operating on a production function which exhibits diminishing productivity, implying that a stage of production has been reached where output is less responsive to fertilizer input. Thus, there is less rationale for substantially changing fertilizer use in response to changes in relative fertilizer-output prices.

However, fertilizer use appears to have become more responsive to fertilizer price as measured by the general upward movement (absolutely) in the sum of the elasticities over time for all formulations considered. For the more reliable formulations (i.e., the static formulation, an example of which is model (3.b)), this sum has trended downward from -.5 in 1949 to -.7 in 1964. Thus, the sum has trended toward -1.0, the point at which the fertilizer supply industry maximizes total revenue. This may be the result of firms supplying fertilizer to farmers attempting to maximize total sales. Such an implication, however, deserves further study before it can be substantiated.

In comparing the results for the static and dynamic models, we find that the coefficients implied by the former model are generally larger than the long-run coefficient implied by the latter model (except for the elasticity on fertilizer price). On the basis that the static model reflects some short-run considerations, however, we would expect just the opposite. Moreover, these results are not altered substantially if the coefficients are assumed subject to random variation rather than being constant at a given point in time. In fact, the random coefficient formulations do not appear to be worth the effort in the case of fertilizer demand, i.e., a meaningful amount of additional information is not obtained.

Table 3.--Random models

Equation number	Dependent variable	N	Year	$\hat{b}_1$	$\hat{b}_2$	$\hat{b}_3$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_3$	
5.a'	Y''	192	49-64	-.714	.896	-.825	.005	.091	.246	
5.b'	Y''	48	49	-.973	1.459	-.948	.000	.086	1.151	
5.b'	Y''	48	54	-.739	.931	-.803	.000	.006	.013	
5.b'	Y''	48	59	-.661	.649	-.668	.000	.009	.006	
5.b'	Y''	48	64	-.638	.438	-.498	.000	.004	.005	
				$\lambda\hat{b}_1$	$\lambda\hat{b}_2$	$\lambda\hat{b}_3$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_3$	λ
6.a'	Y''	144	54-64	-.231	.063	-.162	.001	.012	.040	.391
6.b'	Y''	48	54	-.294	.120	-.174	.000	.006	.025	.437
6.b'	Y''	48	59	-.059	-.121	-.018	.000	.002	.001	.174
6.b'	Y''	48	64	-.128	-.040	-.130	.001	.006	.007	.305
	Long run:									
	Y''		54-64	-.591	.161	-.414				
	Y''		54	-.673	.275	-.398				
	Y''		59	-.339	-.695	-.103				
	Y''		64	-.420	-.131	-.426				

The dummy variable formulation of both the static and dynamic models leads to improved results for the former, but dubious results for the latter. The dynamic model results are affected by estimation problems confronted by including regional dummy variables as well as lagged values of the dependent variable in the same regression. Thus, Griliches' previous conclusion that a dynamic adjustment model may "not represent a very useful approach to cross-section data" (3, p. 838) is not altered by the introduction of dummy variables and several cross-sections over time.

Of those models considered, the most useful for explanation or prediction purposes is the nonrandom static regional dummy variable model (3.c). This reasonably simple model is not confronted with the estimation problems prevalent in the dynamic and random versions. It reflects adequately the long-run differentials in fertilizer demand while providing satisfactory estimates of the unknown parameters, and explains a major portion of the total variation in fertilizer use per acre.

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BOOK REVIEWS

Natural Resource Information for Economic Development

By Orris C. Herfindahl. Published for Resources for the Future, Inc., by the Johns Hopkins Press, Baltimore, Md. 212 pages. 1969. $7.

Exploration economics and the effective use of natural resource information for developing countries are described in this book. The author presents practical concepts from which policymakers may derive effective development strategies.

Early in the book Herfindahl points out the dilemma of collecting data in developing countries. Government agencies collect too little relevant information on resources--or they collect too much. The author leaves the impression that, most frequently, they collect too much--and a great deal of uncertainty exists regarding its use and application.

The impression should not be given that this is a "toolmaker's" book, because it isn't. Traditional ideas about the role of capital and natural resources in development relationships are discussed early. This early section merges neatly, however, with subsequent discussions of the usefulness and capabilities of other tools for deriving resource information. These tools include, among others, soil surveys, aerial photos, and possibly, orbiting sensors.

The major emphasis of this book is on how information systems can be used to provide inputs for government programs of natural resource development. Herfindahl repeatedly stresses that information on natural resource development is capital. He asserts that, while this is not a new concept, viewing investments in natural resource information in this manner will aid in its organization and administration for final investment decisions.

One of the most useful sections of this book, although all too brief, is chapter IV. In it, Herfindahl has assembled natural resource data about Latin America from many different sources, and seasoned it with personal observations made during his stay there.

He developed simplified investment models to illustrate that better performance in resource use is possible. His case is well-documented, even though optimality is specified in his models. He implies that a relationship exists between the marginal cost of information and the marginal returns derived from its concomitant development.

Policymakers and planners should find useful ideas on organization of information activities in chapter VI. Two strong points are made here: (1) It is impossible to collect all the "necessary" information to solve a problem because its solution would depend on information gathered earlier, and (2) it is desirable to collect only enough information to meet the needs because excess data are irrelevant.

Although we can't estimate the value of information, Herfindahl points out that we should be able to specify marginal changes in organization and administration of resource information programs over time. He also raises a question for both developing and developed countries: Should studies of natural resources be integrated, i.e., should several types of data be collected simultaneously?

In summary, Herfindahl makes three strong points in his book: (1) Information, like other inputs, costs money; (2) information is a type of investment; and (3) information, to be effective, must have a strategy employing economic theory in its use. He makes all these points well.

Dwight M. Gadsby

America the Vanishing: Rural Life and the Price of Progress

Edited by Samuel R. Ogden. Stephen Greene Press, Brattleboro, Vt. 242 pages. 1969. $6.95.

The protection of our environment has become a major public issue. Fortunately, some people in the past have seen the problems and have provided bases for action. The Department of Agriculture, particularly, has long urged and carried out programs for the protection of our natural resources--water, land, forests, and vegetation.

Throughout our history, Americans have written of the beauties of nature and of the destruction of resources. In the present anthology, 36 authors express themselves on one or another of these topics. The volume is divided into five sections subtitled "The Unspoiled

Land," "Years of Spacious Living," "Going Back to the Soil," "The Price of Progress," and "Looking for a Silver Lining."

Thomas Morton wrote in his journal of New England in 1622: "...with all her faire indowments, I do not think that in all the knowne world it could be paralel'd." Near the end of the volume, Barry Commoner writes: "As a biologist, I have reached this conclusion: we have come to a turning point in the human habitation of the earth....continued pollution of the earth, if unchecked, will eventually destroy the fitness of this planet as a place for human life...."

Between Morton and Commoner, such writers as John Audubon, John Muir, Henry David Thoreau, Hamlin Garland, David Grayson, E. B. White, and Rachel Carson trace the changes from a rural society in an unspoiled environment to an industrial society in a nearly ruined environment. Economic development in this Nation is exacting a price, and farming is deeply involved.

This nicely designed and printed volume, with a number of apt illustrations, is recommended to the economist interested in a philosophical and literary approach to the environmental crisis facing us today.

Wayne D. Rasmussen

Building Cooperative Movements in Developing Countries—the Sociological and Psychological Aspects

By Konrad Engelmann. Frederick A. Praeger, New York, Washington, London. 239 pages. 1968. $15.

This book should appeal to students of cooperation and particularly to those having a working interest in the development of cooperatives in emerging countries. The author is a highly competent student and practitioner of cooperative development in these countries.

As the title indicates, emphasis is on the sociological and psychological aspects of cooperative development. Obstacles to progress in cooperative movements are examined as well as factors that appear responsible for success. These are some of the highlights of Engelmann's book.

Strong nationalism is viewed as both a favorable and an unfavorable influence to cooperative development. On the positive side, cooperative development can be tied in with nationalism as a patriotic duty, as has been done in Egypt. This does not disturb the author, provided proper safeguards are taken to insure the eventual establishment of cooperatives as democratic enterprises. On the negative side, strong nationalism is often coupled with undemocratic measures on the part of political leaders. This can lead to use of cooperatives primarily for political purposes.

Government initiative and aid in building cooperative movements are considered an absolute necessity in most developing countries. The danger of government-sponsored cooperatives becoming tools to implement state policies is recognized but is not considered incompatible so long as the ultimate objective of cooperatives as economic enterprises is maintained.

A definite distinction is made between government-sponsored cooperatives combined with educational efforts and cooperative development as carried out in most Communist countries. Cooperative development in most Communist countries is viewed as a misuse of these enterprises to undermine private ownership, destroy individual action, and suppress basic principles of cooperation.

In every chapter, the importance of education in general and cooperative education in particular is emphasized. The author has a firm conviction that cooperative development cannot succeed in the absence of adequate understanding by the majority of those to be served.

The author suggests that the foundation of cooperative development should be laid in small districts. Here there is a better understanding of needs and less chance of bureaucratic obstruction and delay.

For those interested in the role of cooperatives in land reform programs, the author's appraisal of the "Nawag" experiment that was conducted in Egypt beginning in 1955 is informative. He considers it to be the turning point in that country's agrarian-reform program.

On coordination of cooperative aid to developing countries, the author recommends a system of compulsory mutual exchange of information among all organizations and institutions working on cooperative development in a country. I find this idea difficult to accept. It seems illogical to argue, as the author does, for cooperation on a democratic basis and then to say that coordination must be compulsory.

Another idea advanced in this book that I have some difficulty with is that the progress of cooperative development has often been retarded because of overemphasis on technical factors and neglect of human and social aspects. I believe many cooperative students would hold just the reverse.

Cooperative monopolism is rejected as being just as detrimental to economic development as monopolism by proprietary enterprises.

On cooperative farming the author is cautious, stating: "No form of cooperation presents graver sociological and psychological problems than cooperative production."

These are some of the interesting ideas in this book. There are more. Its author is to be commended for his significant information and insights on the building of cooperative movements in developing countries.

Job K. Savage

Readings in the Modern Theory of Economic Growth

By Joseph E. Stiglitz and Hirofumi Uzawa. The M.I.T. Press, Cambridge, Mass. 497 pages. 1969. $12.50.

Our national policy of increasing economic growth, induced in part by the Cold War rivalries among the major world powers, has attracted wide attention to the subject. The interest in growth goes beyond the desire for increased standards of living; the continuous formulation of new growth techniques and tools has become almost indispensable to the national survival of this country.

The readings in this book try to analyze the basic structure of the processes of economic growth. The main purpose of modern theory is to understand allocations in the output, employment, and capital stock of a growing economy and the movement in the distribution of income among the factors of production. The empirical facts that the modern theory of growth attempts to explain are quite different from those which were faced by classical theory. As an illustration, part III describes how the Cambridge Growth and Distribution Theory differs from the neoclassical model, and shows how modern theory of growth questions the fundamental empirical laws expounded by classical theory.

The major readings discuss the basic growth models of Harrod, Domar, Tobin, Solow, and Swan (most of the other readings are comments on these basic models). Modern theory makes significant criticisms of the fundamental empirical laws but, because of divergent study results, falls short of invalidating them. As a case in point, in questioning Harrod's principle of the neutrality of technical change, Solow asserts that an estimated 88 percent of the growth of output per man was due to technological change, while Jorgensen and Griliches contend that almost none of the growth in output per man is attributable to technical change.

One major difference in the two theories is their attitudes toward the investment function. In neoclassical models no essential consideration is given to investment. In modern theory, the determination of investment follows the Keynesian approach: At any point in time, the level of investment is fixed; the elasticity of investment with respect to variations in monetary and fiscal policy during this period may be negligible.

On overall examination, the differences between the two schools are understandable. The neoclassicists are committed to an economic theory that assumes rational motivation, while the modern theories assume that man is not moved only by economic motives. Therefore, each school erects models structured to be consistent with its belief in economic behavior. Obviously, the results will be different.

The book is valuable in that it cites the important argument in growth theory. It is important, however, to note that on neither side is there complete agreement on all points. Accordingly, no basic tenet defining the differences between the two will ever be agreed upon by either side.

Jack Ben-Rubin

Capital and Development Planning

By Sukhamoy Chakravarty. The M.I.T. Press, Cambridge, Mass. 344 pages. 1969. $12.50.

Professor Chakravarty states that the intention of his book is "to explore in some detail the theory of optimal economic growth, which has developed during the last decade or so, and to indicate the insights this theory can offer into the problems of planning capital investment decisions." Using the technique of variational calculus and the principles developed by Bellman and Pontryagin, Professor Chakravarty proceeds to elucidate the mathematical theory of intertemporal planning.

He adopts the utility maximizing approach and starts by considering the main choice variables that are present in the notion of an intertemporal optimum: the problems of choosing the length of the planning horizon, problem of choosing the desired terminal stock of capital if the planning horizon is finite, and choosing an intertemporal utility function. These problems are considered in the context of both simple aggregative models and multisector models.

In chapters 2 through 4, the discussion emphasizes the aggregative aspects of an optimal investment program and ignores the structural features connected with an investment program. In finite aggregative models, the problem is formulated to maximize an integral of instantaneous utilities over the given time, subject to initial and terminal capital stock restrictions. One awkward feature of these models is the phenomenon of capital decumulation in the terminal year. However, as the author points out through helpful numerical illustrations, this difficulty can be eliminated by appropriate assumptions as to the marginal utility schedule relative to the terminal stock ratio. The alternative is to use an infinite-horizon model. In such a model, if population is assumed to increase indefinitely at an exponential rate, there appears the problem of choosing to maximize utility on a per capita basis or on a total basis. When per capita consumption is involved in the utility function, then we have a meaningful solution; the "golden rule" path gives maximum indefinitely sustainable utility of consumption per capita. When utility is measured in total terms, such a reference path can no longer be used as a bounding device for arbitrary feasible paths. Thus, one is back to the choice of using a finite planning horizon with all its difficulties, expressing preferences on a per capita basis, or using a discount factor for time.

These models show that inability to reach the desired future rate of capital formation is due to unwillingness to reduce current consumption. An equally important factor, in the short run, is the limited capacity of the domestic capital goods industry. In chapter 5, Chakravarty considers two-sector models with shiftable and nonshiftable capital. In the shiftable capital model, he demonstrates that the optimal time path is independent of the productivity of capital in producing consumer goods. With nonshiftable capital, however, the optimal solution generally implies a mixed policy of first letting consumption remain constant and then following an exponential time path for consumption. In the latter case, the major problem seems to be the determination of appropriate switching points.

In chapters 6 through 8, the main concern is with linear multisector models in the context of both a Leontief and a Von Neuman economy. Chapter 6 deals with problems of existence of growth paths, their uniqueness, and the requirements of nonnegativity. The author demonstrates that an open dynamic model is well suited for determining the terminal levels of capital stocks in the different sectors and shows that within an indecomposable dynamic Leontief model there lies a particular solution that ensures a maximum equiproportionate growth rate for all sectors. However, if the models rule out excess capacity, then, starting from arbitrary initial conditions, one may get configurations involving negative output levels or negative values for capital stock. Thus, the models would lose any predictive or normative significance. As a result, in chapter 7, the dynamic Leontief model is generalized with the introduction of nonnegativity constraints and a terminal capital sector in the form of a boundary condition on a problem involving temporal utility maximization. But again, there is the problem of flip-flop behavior associated with linear technologies. Chapter 8 developes the same theme further but with the assumption of a nonlinear objective function.

Thus, Chakravarty does an excellent job in providing insights to the problems of planning capital investment decisions. However, contrary to his assumption that the mathematics used in this volume is well within the reach of anybody who has a working knowledge of calculus and matrix algebra, including linear programming, many economists will find it difficult to follow the various mathematical arguments, derivations, and proofs. For those who do have a "working" knowledge, the appendices to this volume provide an excellent summary of different optimization techniques. Others might want to consult first a book like R.G.D. Allen's Mathematical Analysis for Economists.

The reviewer's only complaint is not so much with Chakravarty as it is with the "profession" in general, that is, the assumption that the supply of capital is the major obstacle to growth. This may be true for underdeveloped economies, but it is quite debatable in the case of developed economies and especially in regional development, where the availability of skilled labor might be more crucial. Furthermore, Chakravarty dismisses the consistency approach in favor of utility maximization. In planning regional development, where to date little has been done, the complexity of the problems may warrant the use of consistency models where one does not seek to maximize any explicit welfare function. However, the volume does serve as a valuable treatise for researchers concerned with developmental questions. It not only provides the necessary mathematics but should give new vistas for researchers concerned with regional and rural area development.

M.F. Petrulis

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